**Chapter 2 Section 2: Minerals**

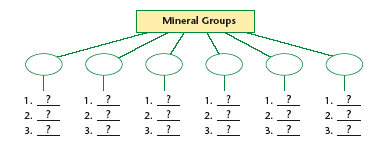
**Key Concepts**

**Vocabulary**

* [mineral](javascript:openCrossRef('../ch2/ch2_s2_1.html%23lnk45.2'))
* [silicate](javascript:openCrossRef('../ch2/ch2_s2_3.html%23lnk47.2'))
* [silicon-oxygen tetrahedron](javascript:openCrossRef('../ch2/ch2_s2_3.html%23lnk47.3'))
* [What are five characteristics of a mineral?](javascript:openCrossRef('../ch2/ch2_s2_1.html%23lnk45.2'))
* [What processes result in the formation of minerals?](javascript:openCrossRef('../ch2/ch2_s2_2.html%23lnk45.9'))
* [How can minerals be classified?](javascript:openCrossRef('../ch2/ch2_s2_3.html%23lnk47.2'))
* [What are some of the major groups of minerals?](javascript:openCrossRef('../ch2/ch2_s2_3.html%23lnk47.2'))

**Reading Strategy**

**Previewing** Copy the organizer below. Skim the material on mineral groups on pages 47 to 49. Place each group name into one of the ovals in the organizer. As you read this section, complete the organizer with characteristics and examples of each major mineral group.



Look at the saltshaker in Figure 9B. This system is made up of the metal cap, glass container, and salt grains. Each component is made of elements or compounds that either are minerals or that are obtained from minerals. In fact, practically every manufactured product that you might use in a typical day contains materials obtained from minerals. What other minerals do you probably use regularly? The lead in your pencils actually contains a soft black mineral called graphite. Most body powders and many kinds of make-up contain finely ground bits of the mineral talc. Your dentist’s drill bits contain tiny pieces of the mineral diamond. It is hard enough to drill through your tooth enamel. The mineral quartz is the main ingredient in the windows in your school and the drinking glasses in your family’s kitchen. What do all of these minerals have in common? How do they differ?

**Figure 9 A** Table salt is the mineral halite. **B** The glass container is made from the mineral quartz. Bauxite is one of the minerals that provides aluminum for the cap.

**Minerals**

A mineral in Earth science is different from the minerals in foods. **A** [**mineral**](javascript:openGlossaryWnd('e_ga_06_mineral')) **is a naturally occurring, inorganic solid with an orderly crystalline structure and a definite chemical composition.** For an Earth material to be considered a mineral, it must have the following characteristics:

1. **Naturally occurring** A mineral forms by natural geologic processes. Therefore, synthetic gems, such as synthetic diamonds and rubies, are not considered minerals.
2. **Solid substance** Minerals are solids within the temperature ranges that are normal for Earth’s surface.
3. **Orderly crystalline structure** Minerals are crystalline substances which means that their atoms or ions are arranged in an orderly and repetitive manner. You saw this orderly type of packing in Figure 5 for halite (NaCl). The gemstone opal is not a mineral even though it contains the same elements as quartz. Opal does not have an orderly internal structure.
4. **Definite chemical composition** Most minerals are chemical compounds made of two or more elements. A few, such as gold and silver, consist of only a single element (native form). The common mineral quartz consists of two oxygen atoms for every silicon atom. Thus the chemical formula for quartz would be SiO2.
5. **Generally considered inorganic** Most minerals are inorganic crystalline solids found in nature. Table salt (halite) is one such mineral. However, sugar, another crystalline solid is not considered a mineral because it is classified as an organic compound. Sugar comes from sugar beets or sugar cane. We say “generally inorganic” because many marine animals secrete inorganic compounds, such as calcium carbonate (calcite). This compound is found in their shells and in coral reefs. Most geologists consider this form of calcium carbonate a mineral.

**How Minerals Form**

Minerals form nearly everywhere on Earth under different conditions. For example, minerals called silicates often form deep in the crust or mantle where temperatures and pressures are very high. Most of the minerals known as carbonates form in warm, shallow ocean waters. Most clay minerals form at or near Earth’s surface when existing minerals are exposed to weathering. Still other minerals form when rocks are subjected to changes in pressure or temperature. **There are four major processes by which minerals form: crystallization from magma, precipitation, changes in pressure and temperature, and formation from hydrothermal solutions.**



**Crystallization from Magma**

Magma is molten rock. It forms deep within Earth. As magma cools, elements combine to form minerals such as those shown in Figure 10 on page 45. The first minerals to crystallize from magma are usually those rich in iron, calcium, and magnesium. As minerals continue to form, the composition of the magma changes. Minerals rich in sodium, potassium, and aluminum then form.

**Hornblende**

Feldspar

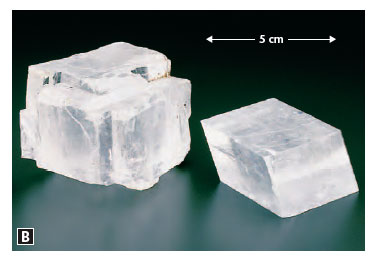


Muscovite

**Figure 10** These minerals often form as the result of crystallization from magma.

Quartz

**Precipitation**

The water in Earth’s lakes, rivers, ponds, oceans, and beneath its surface contains many dissolved substances. If this water evaporates, some of the dissolved substances can react to form minerals. Changes in water temperature may also cause dissolved material to precipitate out of a body of water. The minerals are left behind, or precipitated, out of the water. Two common minerals that form in this way are shown in Figure 11.

**Figure 11 A** This limestone cave formation is an obvious example of precipitation. **B** Halite and calcite are also formed by precipitation.

**Pressure and Temperature**

Some minerals, including talc and muscovite, form when existing minerals are subjected to changes in pressure and temperature. An increase in pressure can cause a mineral to recrystallize while still solid. The atoms are simply rearranged to form more compact minerals. Changes in temperature can also cause certain minerals to become unstable. Under these conditions, new minerals form, which are stable at the new temperature.

**Hydrothermal Solutions**

A hydrothermal solution is a very hot mixture of water and dissolved substances. Hydrothermal solutions have temperatures between about 100°C and 300°C. When these solutions come into contact with existing minerals, chemical reactions take place to form new minerals. Also, when such solutions cool, some of the elements in them combine to form minerals such as quartz and pyrite. The sulfur minerals in the sample shown in Figure 12 formed from thermal solutions.

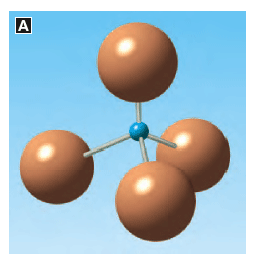
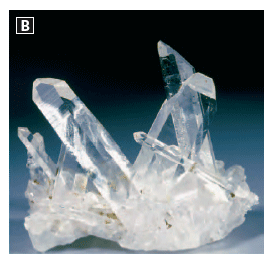
**Figure 12** Bornite (blue and purple) and chalcopyrite (gold) are sulfur minerals that form from thermal solutions.

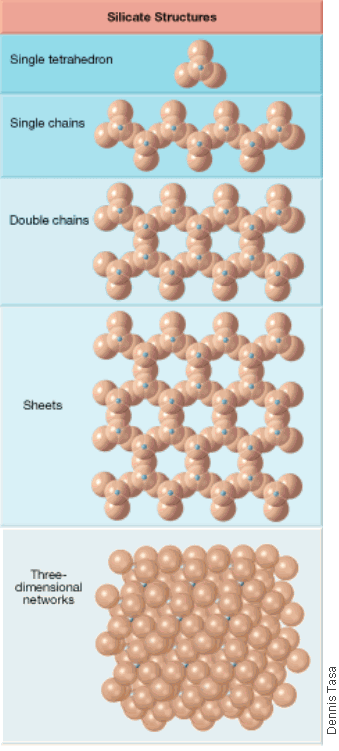
**Mineral Groups**

Over 3800 minerals have been named, and several new ones are identified each year. You will be studying only the most abundant minerals. **Common minerals, together with the thousands of others that form on Earth, can be classified into groups based on their composition.** Some of the more common mineral groups include the silicates, the carbonates, the oxides, the sulfates and sulfides, the halides, and the native elements. First, you will learn about the most common groups of minerals on Earth—the **silicates**.

**Silicates**

If you look again at Table 1, you can see that the two most abundant elements in Earth’s crust are silicon and oxygen. **Silicon and oxygen combine to form a structure called the** [**silicon-oxygen tetrahedron**](javascript:openGlossaryWnd('e_ga_06_slconoxytetr'))**.** This structure is shown in Figure 13. The tetrahedron, which consists of one silicon atom and four oxygen atoms, provides the framework of every silicate mineral. Except for a few silicate minerals, such as pure quartz (SiO2), most silicates also contain one or more other elements.



**Figure 13 A** The silicon-oxygen tetrahedron is made of one silicon atom and four oxygen atoms. The rods represent chemical bonds between silicon and the oxygen atoms. **B** Quartz is the most common silicate mineral. A typical piece of quartz like this contains millions of silicon-oxygen tetrahedra.

Silicon-oxygen tetrahedra can join in a variety of ways, as you can see in Figure 14 on the next page. The silicon-oxygen bonds are very strong. Some minerals, such as olivine, are made of millions of single tetrahedra. In minerals such as augite, the tetrahedra join to form single chains. Double chains are formed in minerals such as hornblende. Micas are silicates in which the tetrahedra join to form sheets. Three-dimensional network structures are found in silicates such as quartz and feldspar. As you will see, the internal structure of a mineral affects its properties.

**Reading Check!**

(a)What is the silicon-oxygen tetrahedron, and in how many ways can it combine?

**Figure 14** Silicon-oxygen tetrahedra can form chains, sheets, and three-dimensional networks. **Formulating Hypotheses** What type of chemical bond is formed by silicon atoms in an SiO4 tetrahedron?

Recall that most silicate minerals crystallize from magma as it cools. This cooling can occur at or near Earth’s surface, where temperatures and pressures are relatively low. The formation of silicates can also occur at great depths, where temperatures and pressures are high. The place of formation and the chemical composition of the magma determine which silicate minerals will form. For example, the silicate olivine crystallizes at temperatures of about 1200°C. Quartz crystallizes at about 700°C.

Some silicate minerals form at Earth’s surface when existing minerals are exposed to weathering. Clay minerals, which are silicates, form this way. Other silicate minerals form under the extreme pressures that occur with mountain building. Therefore, silicate minerals can often provide scientists with clues about the conditions in which the minerals formed.

**Carbonates**

Carbonates are the second most common mineral group. **Carbonates are minerals that contain the elements carbon, oxygen, and one or more other metallic elements.** Calcite (CaCO3) is the most common carbonate mineral. Dolomite is another carbonate mineral that contains magnesium and calcium. Both limestone and marble are rocks composed of carbonate minerals. Both types of rock are used in building and construction.

**Oxides**

**Oxides are minerals that contain oxygen and one or more other elements, which are usually metals.** Some oxides, including the mineral called rutile (TiO2), form as magma cools deep beneath Earth’s surface. Rutile is titanium oxide. Other oxides, such as corundum (Al2O3), form when existing minerals are subjected to changes in temperature and pressure. Corundum is aluminum oxide. Still other oxides, such as hematite (Fe2O3), form when existing minerals are exposed to liquid water or to moisture in the air. Hematite is one form of iron oxide.

**Sulfates and Sulfides**

**Sulfates and sul-fides are minerals that contain the element sulfur.** Sulfates, including anhydrite (CaSO4) and gypsum (CaSO4 • 2H2O), form when mineral-rich waters evaporate. Sulfides, which include the minerals galena (PbS), sphalerite (ZnS), and pyrite (FeS2), often form from thermal, or hot-water, solutions. Figure 15 shows two of these sulfides.



**Figure 15 Sulfides A** Galena is a sulfide mineral that can be mined for its lead. **B** Pyrite is another sulfide that is often called fool’s gold. **Inferring** What element do you think pyrite is generally mined for?

**Halides**

**Halides are minerals that contain a halogen ion plus one or more other elements.** Halogens are elements from Group 7A of the periodic table. This group includes the elements fluorine (F) and chlorine (Cl). The mineral halite (NaCl), table salt, is a common halide. Fluorite (CaF2) is also a common halide and is used in making steel. It forms when salt water evaporates.

**Native Elements**

**Native elements are a group of minerals that exist in relatively pure form.** You are probably familiar with many native elements, such as gold (Au), silver (Ag), copper (Cu), sulfur (S), and carbon (C). Native forms of carbon are diamond and graphite. Some native elements form from hydrothermal solutions.

**Chapter 2 Section 2 Assessment**

**Reviewing Concepts**

(1) What are five characteristics of a mineral?

(2) Describe four processes that result in the formation of minerals.

(3) How can minerals be classified?

(4) Name the major groups of minerals, and give at least two examples of minerals in each group.

**Critical Thinking**

(5) **Comparing And Contrasting** Compare and contrast sulfates and sulfides.

(6) **Formulating Conclusions** When hit with a hammer, quartz shows an uneven breakage pattern. Using Figure 14, what can you suggest about its structure?

(7) **Applying Concepts** To which mineral group do each of the following minerals belong: bornite (Cu5FeS4), cuprite (Cu2O), magnesite (MgCO3), and barite (BaSO4)?

**Writing In Science**

(8) **Explanatory Paragraph** Coal forms from ancient plant matter that has been compressed over time. Do you think coal is a mineral? Write a paragraph that explains your reasoning.